ACTIVE NOISE CANCELLATION IN THE RECTANGULAR ENCLOSURE SYSTEMS

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Abstract- The interior active noise control (ANC) is essential to be explore because it is significant for automobile manufacturer to design noise control systems and interior noise treatments in the automobiles system. In this research, experimental work undertaken for cancelling an active noise in the rectangular enclosure. The rectangular enclosure was fabricated with multiple speakers and microphones inside the enclosure. A software program using digital signal processing is implemented to evaluate the proposed method. Noise is generated by using multi-speaker inside the enclosure and microphones are used for noise measurements. At the end of this research, the result of output noise before and after cancellation are presented and discussed. On the basis of the findings presented in this research, an active noise cancellation in the rectangular enclosure is worth exploring in order to improve the noise control technologies.

Keywords- interior noise control, active noise cancellation, rectangular enclosure, digital signal processing.

I. INTRODUCTION

An important problem in automobile systems is interior car noise such as road noise, wind noise, engine noise and others [1]. To understand this problem it is necessary to study the effect of interior car noise on human. Interior car noise can cause fatigue to the driver and passengers and thus can be a factor of considerable importance to safety. Other than that, high noise level also can lead some injury to hearing [2]. Therefore, it is important to reduce interior car noise to ensure the comfort of the driver and passengers as it has been the key of competition between automobile manufacturers.

In the past decades research has been done to reduce interior noise in the automobile systems. In order to reduce interior noise control, there are two approaches that commonly used which are passive noise control and active noise control. The reducing of interior noise control was first approached by passive noise control methods, where physical treatments such as structural damping and acoustic absorption were used. However, automobile manufacturer demanding for more economical and light weight designs, the resulting car interiors usually became more noisy but in low frequency due to the increased structural vibrations [3]. Passive noise control methods only prove successful at higher frequencies and while technically possible for lower frequencies [4]. As passive noise control methods are suitable for high frequencies noise, it is less effective to reduce interior noise in the automobile systems. Thus, active noise control can be applied in the car interiors to improve noise reduction technologies as it can minimizing the low frequency noise annoyance experienced by the driver and passengers.

The technique of active noise control relies on the basic principle of destructive interference between two sound fields, where the primary source may be assumed to be tonal, the amplitude and phase of the secondary source is driven by a sine wave generator at the same frequency as the primary source but with the phase shifted by 180 degrees. The result is that one field is generated by the original or primary sound source, the other secondary sound source set up to interfere with, and cancel, that unwanted primary sound [5]. The residual difference between the two sound source is measured using a microphones placed inside the rectangular cabin, and is minimized using a feedforward or feedback control systems [6]. Feedforward control systems relies on the existence of some prior knowledge of the disturbance to be controlled, which is reference signal is used to drives the secondary source through the controller, whereas feedback control systems not requiring a reference signal and use a single-input single-output system to reduced overall measured noise [7].

In this paper, anapproach to reduce low frequency noise in the rectangular enclosure using active noise control techniques with the implementation of LabView controller is presented. LabView is a system-design platform and development environment for a visual programming language from National Instruments. The frequency range of interest in this study is from 25-500Hz. In the associated simulations, an analog feedforward control systems are used for noise measurements.

A. DESCRIPTION OF ANC SYSTEM

The ANC system requires physical plant (rectangular enclosure) composed of a noise source (primary speaker), reference and error microphones (sensors), and loudspeakers (actuators) for noise propagation. In order to produce the proper anti-noise signal the system used feedforward technique, where the reference sensor measures the unwanted noise from primary speaker and produces a reference signal that provides information about the acoustic disturbance that the system desired to eliminate the unwanted noise [8]. The control system is trying to reduce the unwanted noise by using the reference signal and added to plant's output to create the error signal which produces the anti-noise signal in accordance with an adaptive control algorithm.

B. ADAPTIVE FEEDFORWARD ANC

The Filtered-X Least Mean Square (FXLMS) Algorithm is the most common adaptive algorithm used for ANC system. The theoretical FXLMS algorithm is implemented in this research as shown in the Fig. 1 [9].

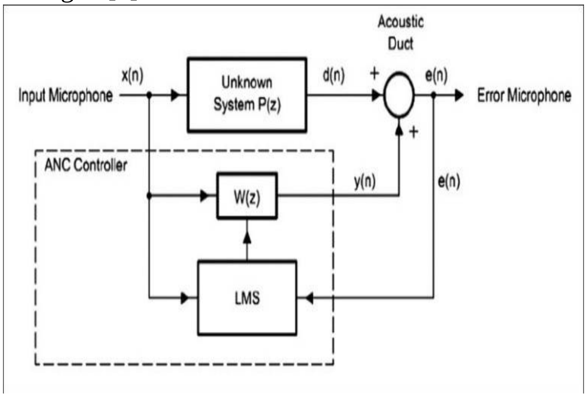

Fig. 1 Adaptive feedforward ANC using FXLMS algorithm

Using a digital frequency domain representation of the problem, the ideal active noise control system uses an adaptive filter W(z) to estimate the response of an unknown primary acoustic path P(z) between the reference input sensor and the error sensor. The z transform of e(n) can be expressed as in Eq. 1:

$$E(z) = D(z) + Y(z) = X(z)[P(z) + W(z)] \tag{1}$$

Where E(z) is the error signal, X(z) is the input signal, and Y(z) is the adaptive filter output. After the adaptive filter W(z) has converged, E(z) = 0. The Eq. 2 becomes:

$$W(z) = -P(z) \tag{2}$$

Then it implies that,

$$y(n) = -d(n) \tag{3}$$

Therefore, the adaptive filter output y(n) has the same amplitude but it is 180 degrees out of phase with the primary noise d(n). When d(n) and y(n) are acoustically combines, the residual error becomes zero, resulting in cancellation of both sounds based on the principle of superposition.

II. RESEARCH METHOD

A. FLOW CHART OF STUDY

Implementation and works of the research are summarized in the flow chart shown in Fig.2. The results obtained following these three important procedures. Before proceed with noise cancellation, the SPL analysis have been conducted as it is the magnitude of the sound pressure wave produced in the rectangular enclosure from the acoustic emissions of a sound source. The frequency obtained from the SPL analysis is the preliminary results to conduct an experimental work based on ANC system. Second, the ANC system was tested with multiple anti-noise and the results will be compared to decide the number of anti-noise used in this research. The results was plotted in the time and frequency domain. Finally, experimental works to reduce or cancel the noise have been done based on the results obtained from the first and second procedure.

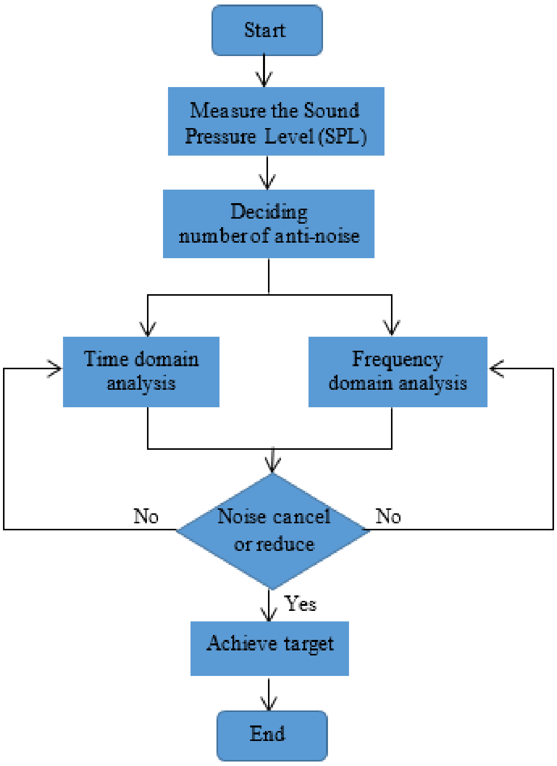

Fig. 2 Flow chart of study

B. EXPERIMENTAL SETUP OF ANC SYSTEM

Fig 3 shows a feedforward ANC system was developed using a digital signal processing equipped with a NI PXIe-1082 embedded controller. The practical experimental setup for noise cancellation studies is shown in Fig. 4. The rectangular enclosure was custom made in the lab with six loudspeakers and six microphones for conducting ANC. The rectangular enclosure having dimensions of 1.285m x 1.230m x 1.790m. To generate the noise disturbance, multiple loudspeakers is mounted inside the rectangular enclosure and is connected to a sine generator to create periodic noise. The cancelling loudspeakers also were located in the rectangular enclosure and microphones are used as reference microphones or error sensors. Users are able to select which microphone and speaker to be either noise source or anti-noise. The position of microphones can be adjust the directionality to suit the experimental setup.

Fig. 3 NI PXIe-1082

Fig. 4 Experimental setup of ANC system

III. RESULTS AND DISCUSSION

The Sound Pressure Level (SPL) was measured to determine the frequency that will be used to conduct an experimental work regarding to performance of the ANC system. The SPL in the rectangular enclosure was measured using the Sound Level Meter NL-52 when noise source generating tonal noise at octave frequencies and plotted in frequency domain as shown in Fig. 5. It can be clearly seen from the Fig. 5 that 200 Hz has the highest SPL (21.3dB) in the low frequency range of 0-500Hz. Thus, the active noise cancellation was measured at the frequency of 200Hz due to the frequency response of the rectangular enclosure.

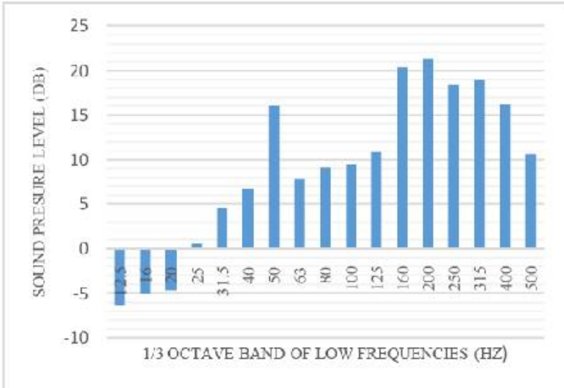

Fig 5 Sound Pressure Level from 0-500Hz

The performance of ANC system was obtained at the 200 Hz, which is shown in Fig. 6, 7, 8 and 9. These figures illustrate the time and frequency domain of the signal before and after noise cancellation.

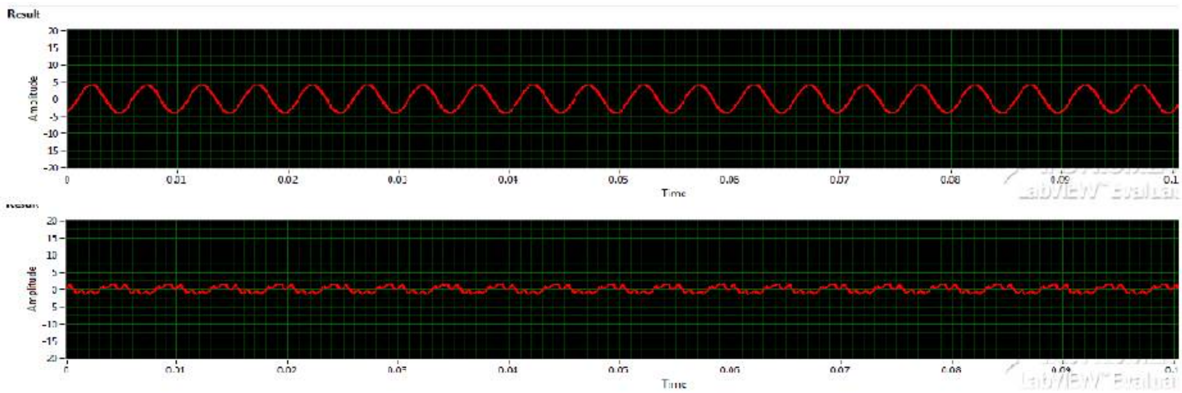

Fig. 6 Time domain before and after cancellation by ANC system (One Anti-Noise)

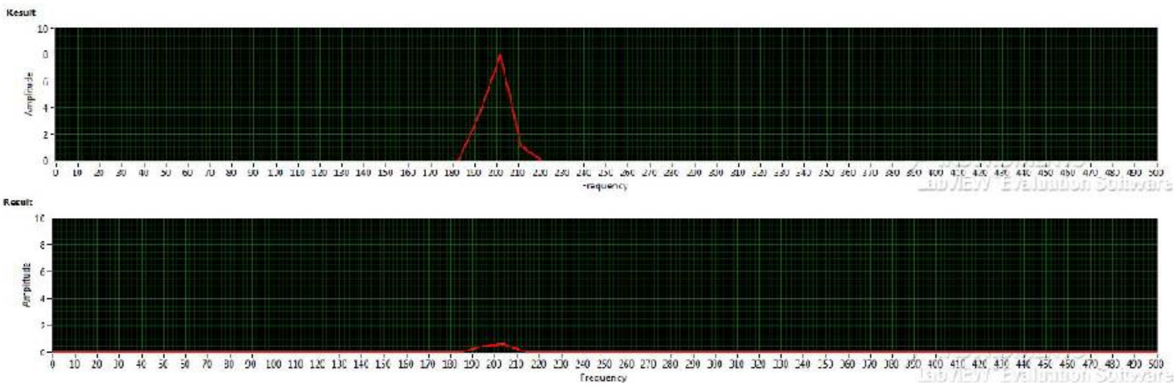

Fig. 7 Frequency domain before and after cancellation by ANC system (One Anti-Noise)

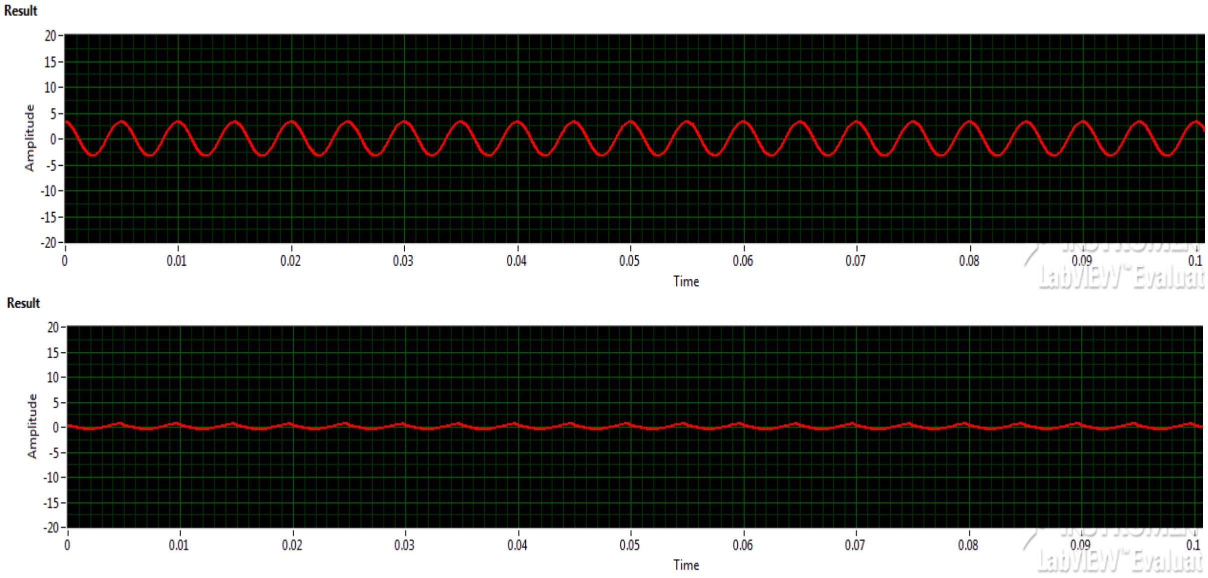

Fig. 8 Time domain before and after cancellation by ANC system (Two Anti-Noise)

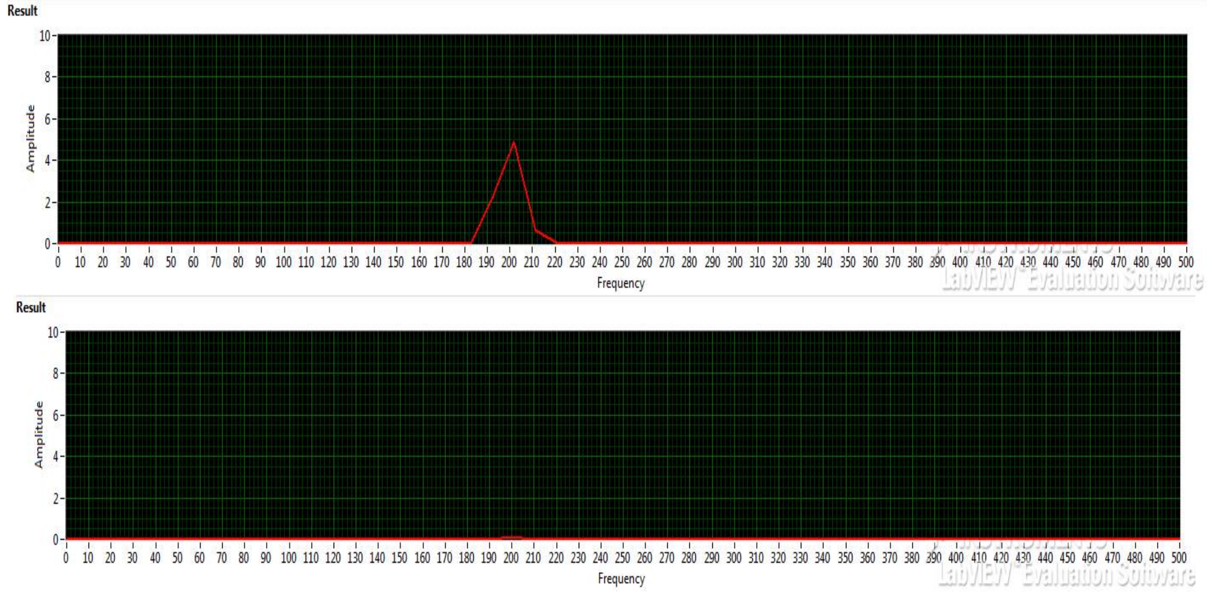

Fig. 9 Frequency domain before and after cancellation by ANC system (Two Anti-Noise)

The effectiveness of noise cancellation depends on the performance of the anti-noise signal and the ability to manipulate the gains of the involved signal. It is very important to adjust the signals detected by the microphones and to control the level of the anti-noise through the cancelling speakers. From the results, it is found that the ANC system using two anti-noise speakers shows the greatest reduction. It is observed that, the noise can be sufficiently cancelled using two anti-noises as shown in Fig. 9. However, less noise cancellation can be seen when using one anti-noise as shown in Fig 7. This is due to the enclosure which is rectangular. The propagation of noise depends up on the topographical features where it is a closed type space. The reflection wave exist, thus one anti-noise is not sufficient to cancel the reflection wave but is sufficient to cancel the incident wave.

CONCLUSIONS

Present study has emphasized the practical aspects of ANC systems in terms of adaptive algorithms and the implementations of digital signal processing in cancelling the unwanted noise. In addition, the platform National Instruments and software LabView was utilized in the algorithm for adaptive signal filtering. The analysis and results of experimental setup are as expected from the feedforward techniques. As a conclusion, the ANC system cancels the unwanted noise relies on the principle of destructive interference by generate anti-noise that has equal amplitude and 180 degrees out of phase.

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